



**Securing
the
Future™**

Accelerating Semantic Digital Thread User Queries using LLMs

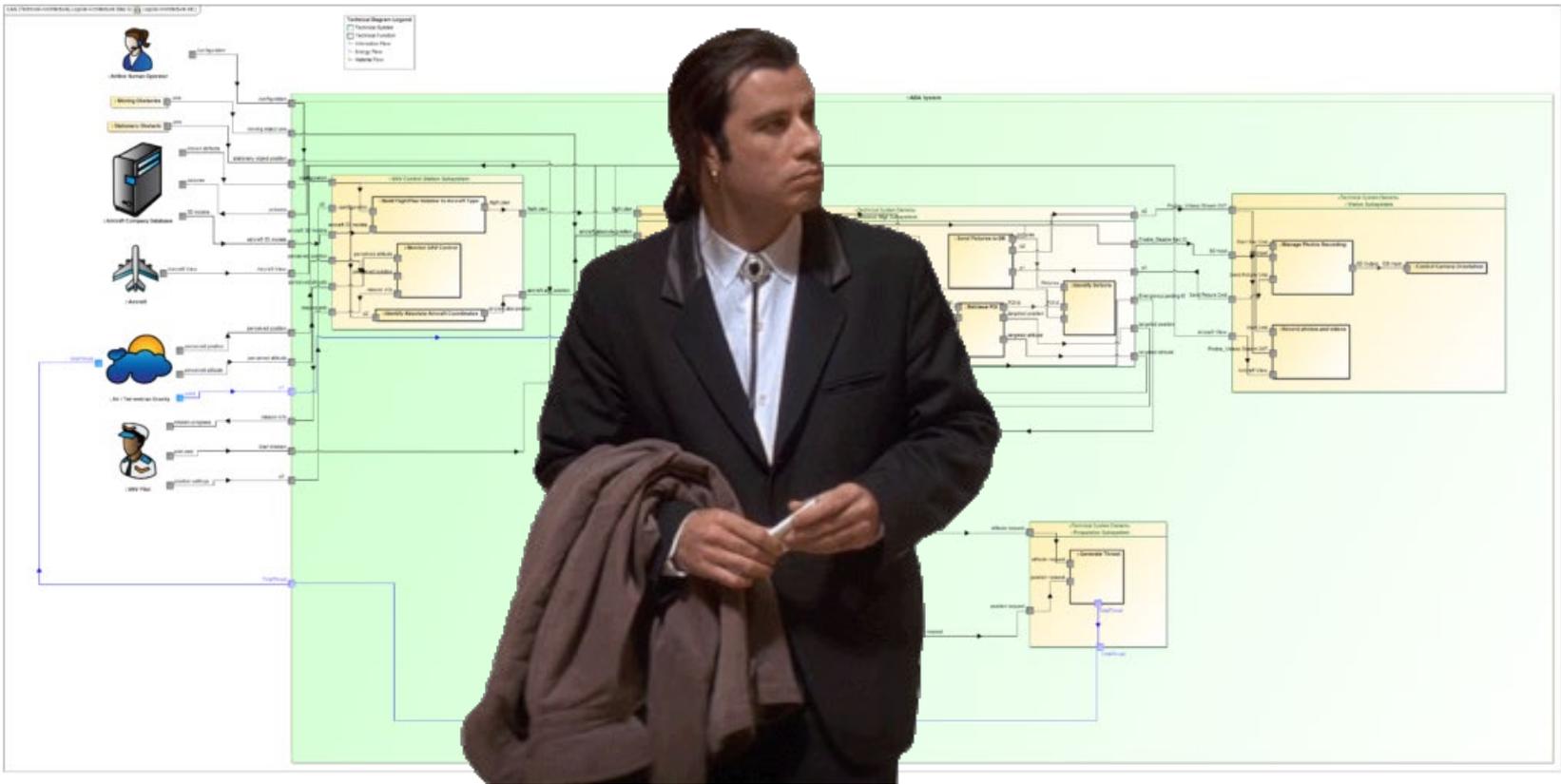
Nicole Manno | Digital Engineer













Ontologically-Backed Digital Thread

- What is it?
 - A digital thread that leverages ontologies to semantically integrate and manage data across the product lifecycle.
- Role of the ontology
 - Provides a structured framework for data
 - Creates semantic meaning for data
 - Denotes common data schema across disparate systems



Ontologically-Backed Digital Thread Benefits

- **Enhances Data Integration**
 - Integration of data from diverse sources
- **Semantic Clarity**
 - Provides clear and unambiguous definitions of terms, relationships, and properties
- **Data Consistency and Quality**
 - Data is consistent, accurate, and of high quality across different systems
- **Inference and Reasoning**
 - Allows the system to infer new knowledge from existing data

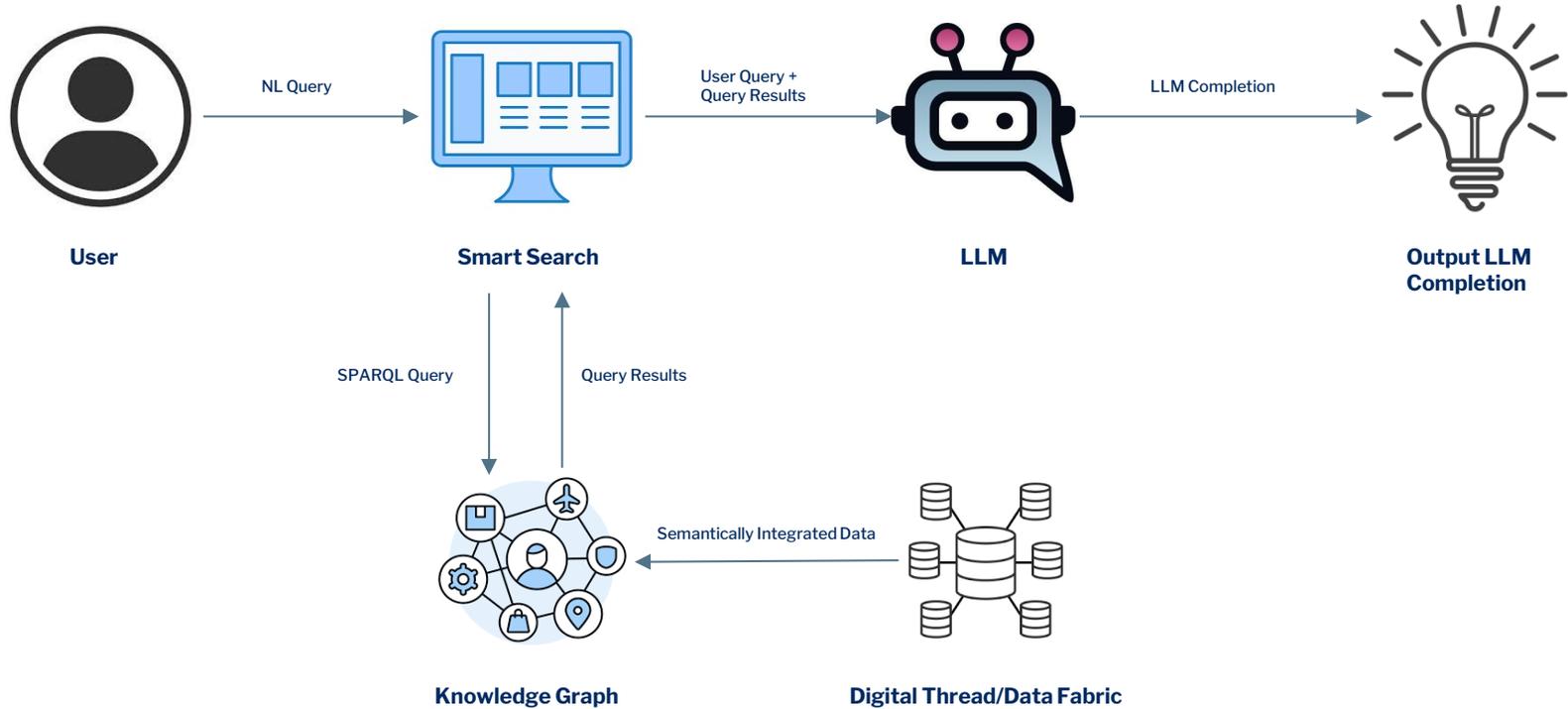


Digital Thread Chatbot

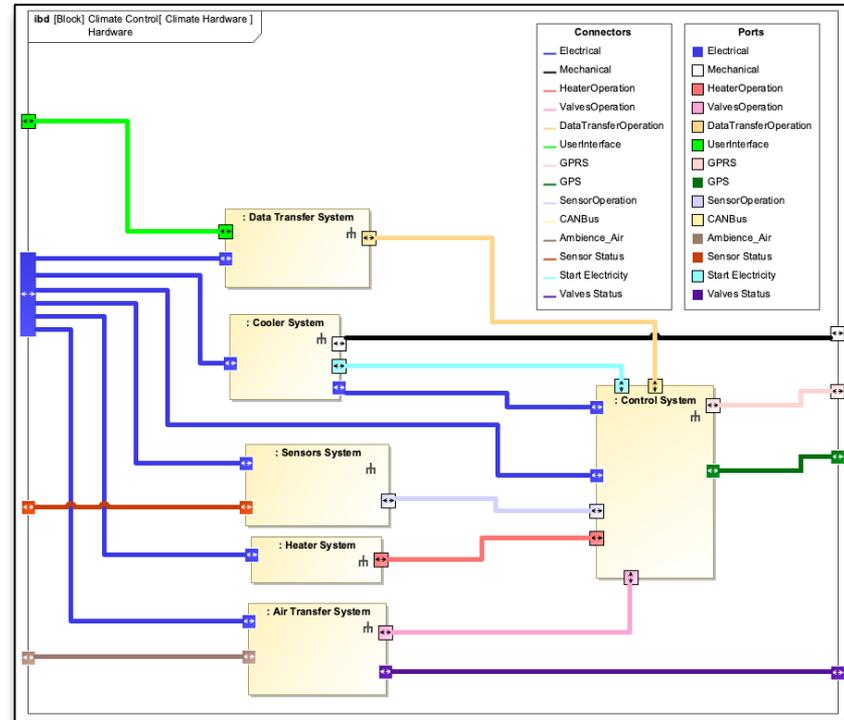
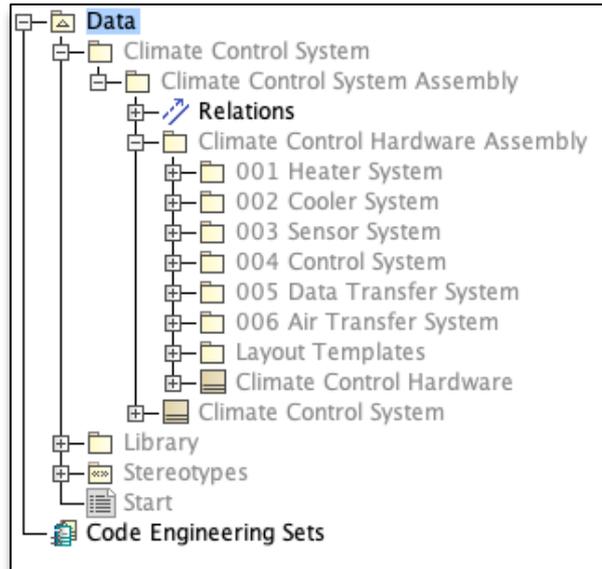
- **Purpose**
 - Ask natural language questions about integrated data in a digital thread or data fabric
 - Engage with data conversationally, as if speaking to an expert who knows the content
- **How?**
 - Knowledge graph
 - Large language model (LLM)
 - Ontology-based question answering system

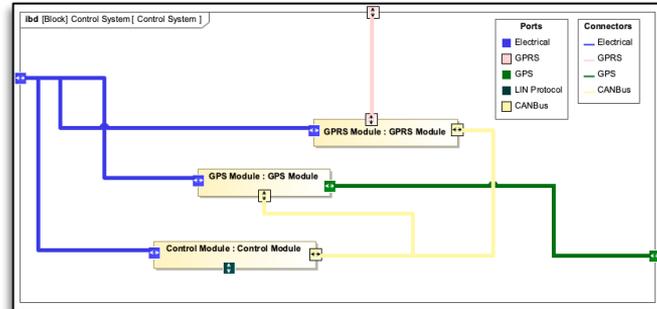
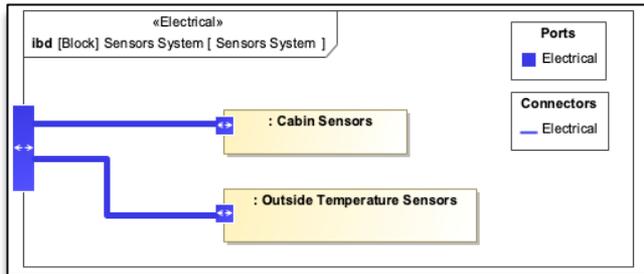
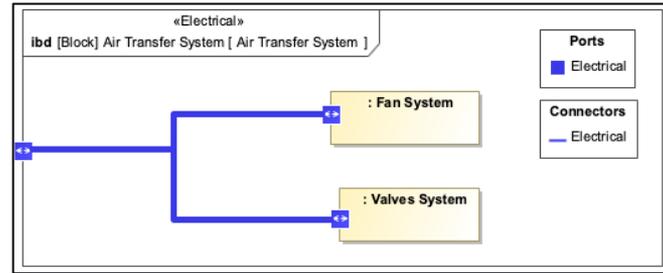
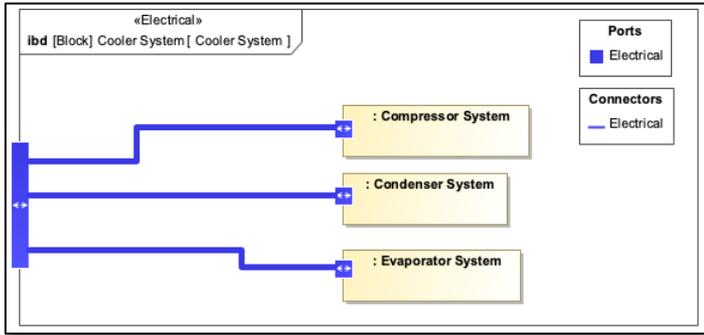
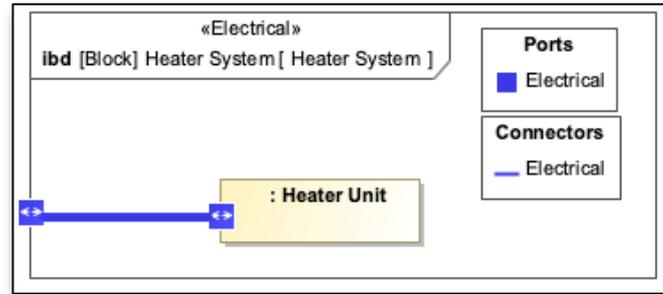
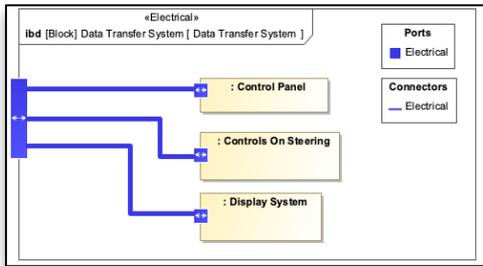


Methodology

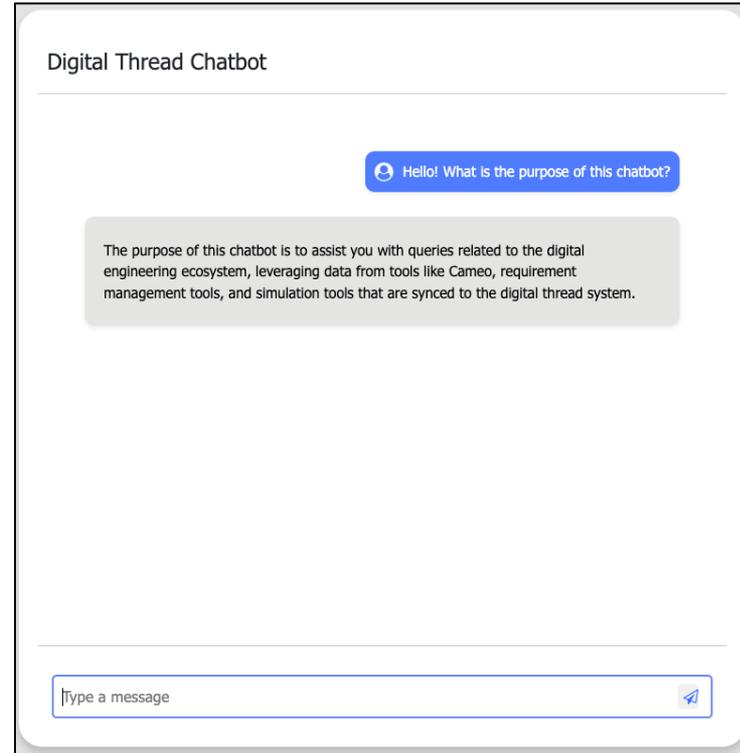
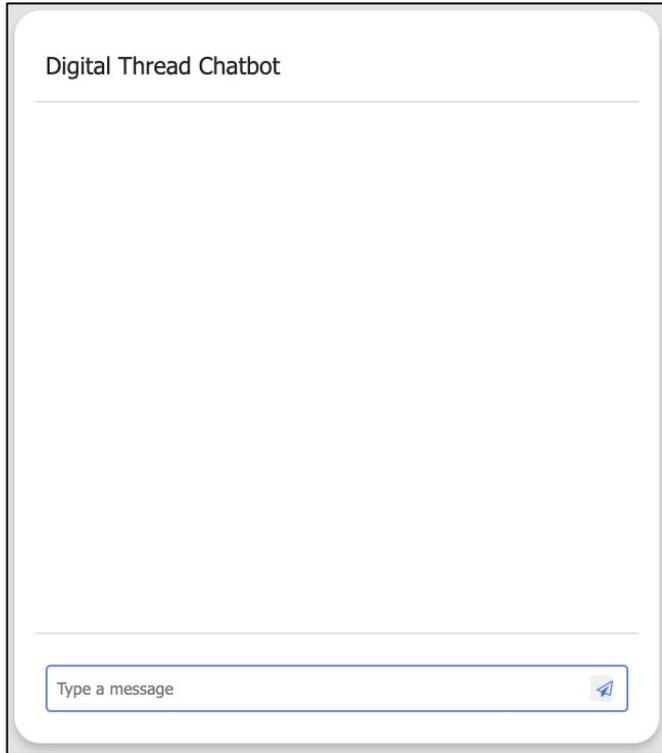


Climate Control System Model





Chatbot Web Interface

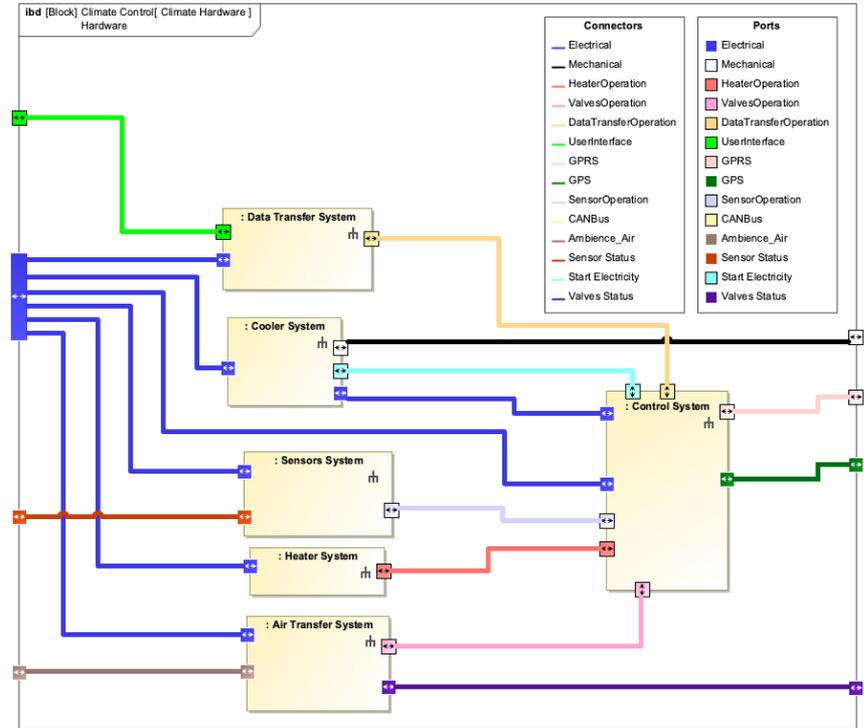


Simple Queries ...

What are the main components of the car's climate control system?

The main components of the car's climate control system are:

1. Data Transfer System
2. Cooler System
3. Sensors System
4. Heater System
5. Air Transfer System
6. Control System



... to More Detailed Queries!



How does the car's climate control system work?

The car's climate control system operates through the interaction of several interconnected subsystems:

1. **Control System:** This is the central hub that manages the overall operation of the climate control system. It receives inputs from various sensors and user controls, processes this information, and sends commands to other subsystems.
2. **Data Transfer System:** This system includes the Control Panel, Controls on Steering, and Display System. It facilitates communication between the user and the climate control system. User inputs are sent to the Control System via the Data Transfer Operation Port.
3. **Sensors System:** This system includes Cabin Sensors and Outside Temperature Sensors. It monitors the internal and external temperatures and sends this data to the Control System.
4. **Cooler System:** This system includes the Compressor System, Condenser System, and Evaporator System. It is responsible for cooling the air. The Control System activates the Cooler System based on the temperature data and user settings.
5. **Heater System:** This system includes the Heater Unit. It is responsible for heating the air. The Control System activates the Heater System as needed.
6. **Air Transfer System:** This system includes the Fan System and Valves System. It manages the distribution of air within the car. The Control System controls the operation of fans and valves to direct air flow as required.

The Control System coordinates these subsystems to maintain the desired cabin temperature by adjusting the cooling, heating, and air distribution based on sensor data and user inputs.



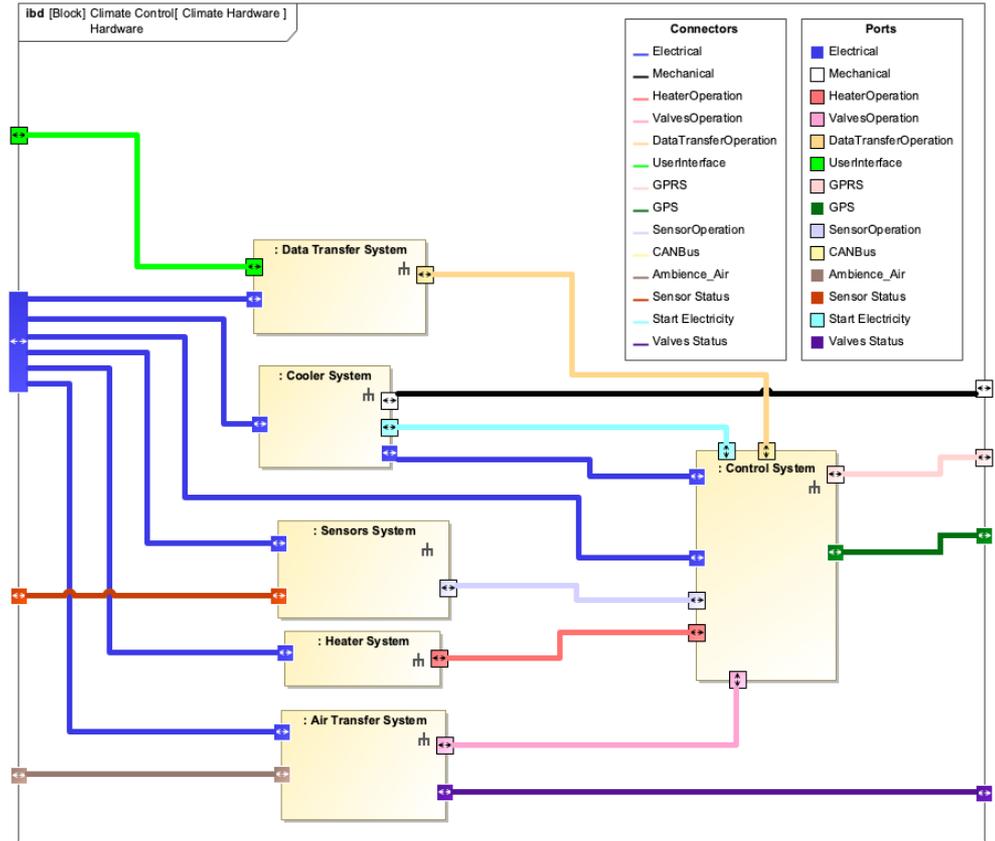
Model Tracing

How Is the Data Transfer System connected to the Heater System In the Climate Control System model?

The Data Transfer System is connected to the Heater System in the Climate Control System model through the following connections:

1. Electrical Connection: Electrical Port 16 on the Data Transfer System is connected to Electrical Port 36 on the Climate Control System, which in turn is connected to Electrical Port 27 on the Heater System.
2. Control Connection: Data Transfer Operation Port 1 on the Data Transfer System is connected to Data Transfer Operation Port 2 on the Control System. The Control System then connects Heater Operation Port 2 to Heater Operation Port 1 on the Heater System.

These connections facilitate both electrical power and operational control data transfer between the Data Transfer System and the Heater System.



Analytical Queries

🗣️ Is there anything missing from the Climate Control System model that would benefit the model?

The Climate Control System model appears to be comprehensive in terms of its components and their interconnections. However, one potential area for improvement could be the inclusion of a feedback mechanism from the user interface to the Control System. This would allow the system to adjust its operations based on user preferences and real-time feedback, enhancing the overall efficiency and user experience. Additionally, integrating a diagnostic system to monitor and report the health status of each component could further benefit the model by ensuring reliability and ease of maintenance.

🗣️ Can you explain the overall architecture of the Control System In the Climate Control System diagram?

The overall architecture of the Control System in the Climate Control System diagram consists of three main components: the GPS Module, the GPRS Module, and the Control Module.

- GPS Module:
 - CAN Port 8 is connected to CAN Port 9 on the Control Module via a CANBus connector.
 - Electrical Port 29 is connected to Electrical Port 31 on the Control System via an Electrical connector.
 - GPS Port 1 is connected to GPS Port 2 on the Control System via a GPS connector.
- GPRS Module:
 - CAN Port 7 is connected to CAN Port 9 on the Control Module via a CANBus connector.
 - Electrical Port 28 is connected to Electrical Port 31 on the Control System via an Electrical connector.
 - GPRS Port 1 is connected to GPRS Port 2 on the Control System via a GPRS connector.
- Control Module:
 - CAN Port 9 is connected to CAN Port 7 on the GPRS Module and CAN Port 8 on the GPS Module via CANBus connectors.
 - Electrical Port 30 is connected to Electrical Port 31 on the Control System via an Electrical connector.

The Control System integrates these modules through various ports and connectors, ensuring communication and power distribution among the components.



Performance Evaluation

- Performance Metrics
 - Intent recognition accuracy
 - Entity recognition accuracy
 - User acceptance testing (UAT)
- Evaluation is still ongoing
 - Test done with a more complicated model, like CubeSat
 - Mix between simple, direct queries and complicated, analytical queries



Future Work

- **Enhance Performance**
 - Improve search accuracy and relevance
 - Faster response time
 - Refine querying processing to handle complex questions
- **Ongoing Development**
 - Performance Evaluation
 - Ontology Expansion
 - Advanced Use Cases



References

- Abdi, Asad & Idris, Norisma & Ahmad, Zahrah. (2016). QAPD: an ontology-based question answering system in the physics domain.
- Allemang, Sequeda. (2024). Increasing the LLM Accuracy for Question Answering: Ontologies to the Rescue! <https://arxiv.org/abs/2405.11706>
- Lopez, Vanessa & Uren, Victoria & Motta, Enrico & Pasin, Michele. (2007). AquaLog: An ontology-driven question answering system for organizational semantic intranets. *Web Semantics: Science, Services and Agents on the World Wide Web*. 5. 72-105. 10.1016/j.websem.2007.03.003.
- Singh, Willcox. (2018). Engineering Design with Digital Thread. *AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference*, vol. 56, no. 11, 11, doi:10.2514/6.2018-0569.
- Vargas-Vera, M., Motta, E. (2004). AQUA – Ontology-Based Question Answering System. In: Monroy, R., Arroyo-Figueroa, G., Sucar, L.E., Sossa, H. (eds) *MICAI 2004: Advances in Artificial Intelligence*. *MICAI 2004. Lecture Notes in Computer Science*, vol 2972. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-24694-7_48
- Xu, Z., Cruz, M. J., Guevara, M., Wang, T., Deshpande, M., Wang, X., & Li, Z. (2024). Retrieval-augmented generation with knowledge graphs for customer service question answering. *arXiv.org*. <https://arxiv.org/abs/2404.17723>





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